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INF2178 Technical Assignment 4 Narrative
Examining the Effects of Dementia on the Human Brain

1. Introduction

Dementia is a collective term used to describe a variety of brain disorders that result in a progressive decline in cognitive functioning, affecting memory, thinking, behavior, and the ability to perform everyday activities. This report seeks to examine the effects of dementia on the human brain by quantifying the changes that occur. We investigate decline in both physical and mental capacities, using normalized whole brain volume (nWBV) and mini-mental state examination (MMSE) scores respectively. Our approach is guided by two research questions:

Research Question 1: How does dementia status affect changes in normalized whole brain volume (nWBV) over time?

Research Question 2: Is the progression of cognitive decline, as measured by Mini-Mental State Examination (MMSE) scores, influenced by dementia status?

To answer these questions, we utilise data from a longitudinal study on MRI results of patients with and without dementia.

2. Exploratory Data Analysis

The dataset covers 150 unique patients, with observations being made in two checkups made at least a year apart. Six patients have only a single visit detailed, resulting in a total of 294 observations in the dataset.

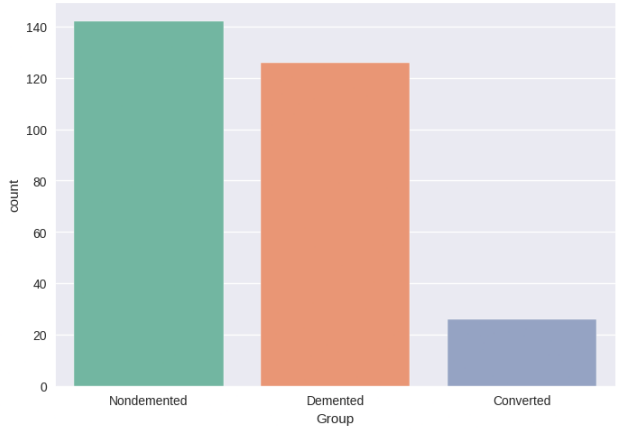

Figure 1: Distribution of Patients by Dementia Status

The observations are classified according to the corresponding patient's dementia status (Figure 1). There are 142 observations taken of patients suffering from dementia, 126 taken of those not afflicted by dementia, and 26 taken of patients that did not have dementia during their first visit but were diagnosed with it by their second visit.

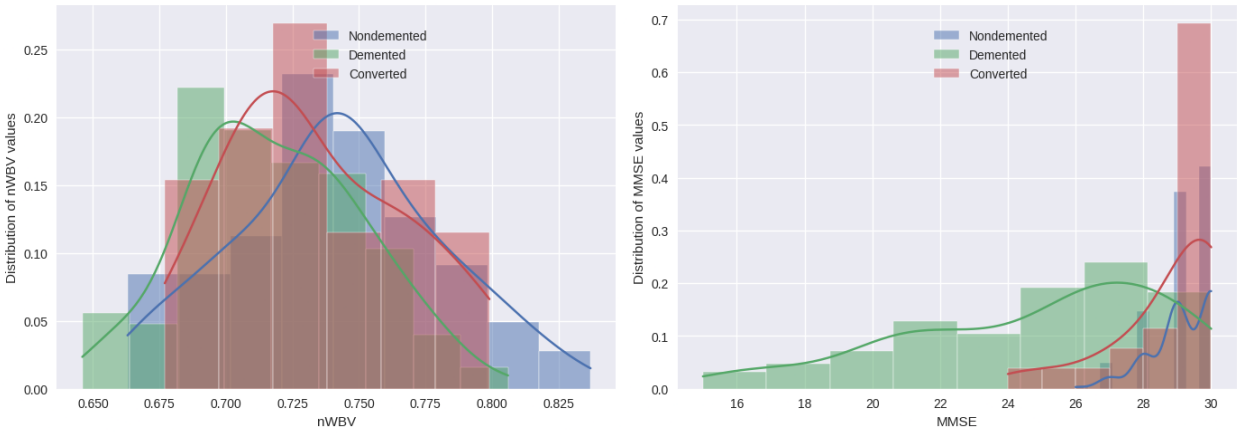

Figure 2: Distributions of nWBV and MMSE Values by Dementia Status

During these visits, the patients had their nWBV and MMSE levels measured (Figure 2). We observe generally normal curves for nWBV, with demented and converted groups showing distributions leaning more towards lower values than the nondemented. MMSE is much more heavily skewed, with most patients in the nondemented and converted groups scoring very highly. The demented group has a much flatter curve with patients distributed broadly across the range of scores.

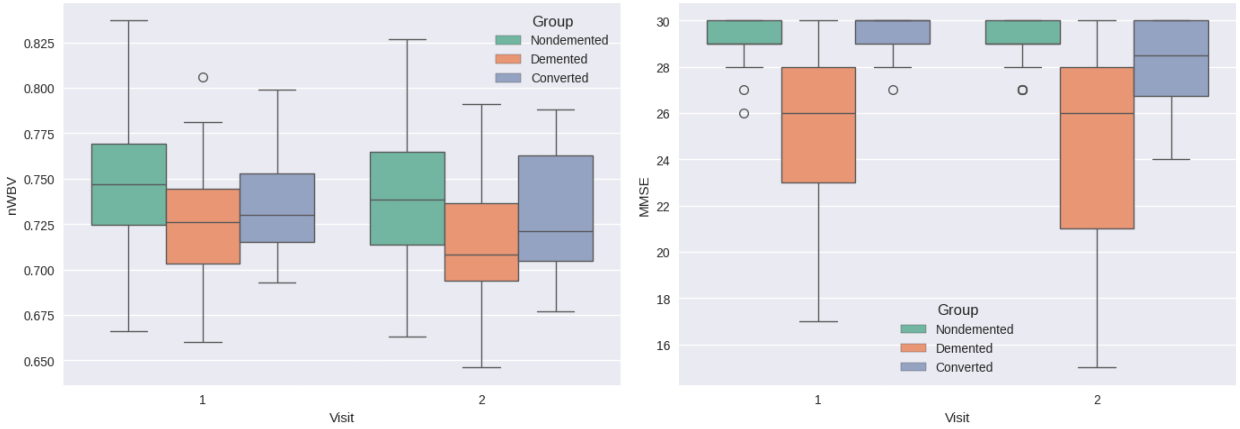

Figure 3: Boxplots of nWBV and MMSE Values by Dementia Status and Visit

In Figure 3 we see that nondemented patients typically score consistently across their two visits, and with more positive performance than the other groups. The demented group has the lowest scores in every case, with noticeably worse scores in their second visit. The converted shows similar performance to the nondemented group in the first visit as expected, but after developing dementia their scores vary much more with an observable decrease in the median. These trends are more clearly visualised in Figure 4 where we observe that for nWBV the relative decrease in performance is equal for the three groups, but for MMSE nondemented patients shows no change in scores while the demented and converted groups decrease.

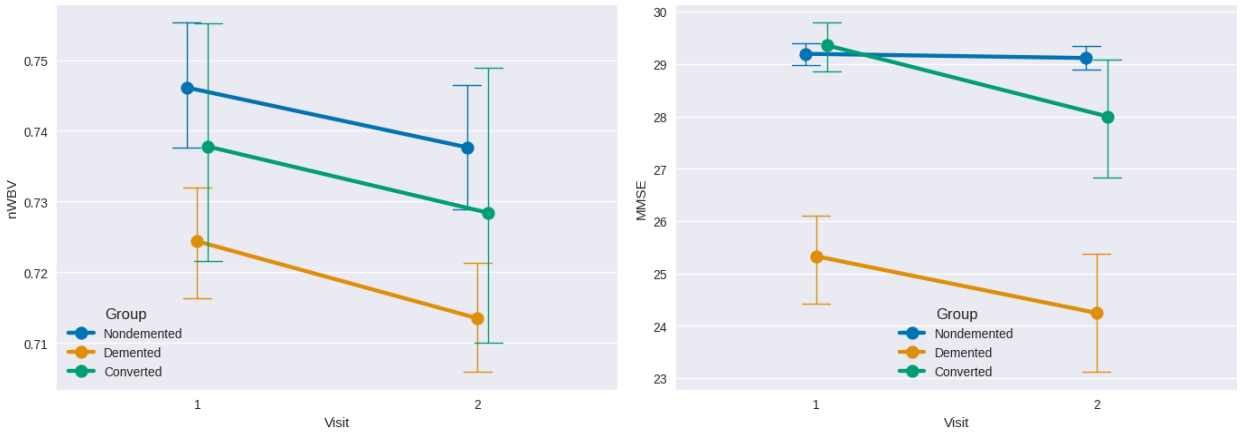

Figure 4: Interaction Plots for nWBV and MMSE by Dementia Status and Visit

3. Results

We conduct two mixed-effects ANOVAs to gauge the changes in nWBV and MMSE by patient group over time. Table 1 shows the results of the ANOVA conducted for nWBV values. For a significance level of .95, the difference in nWBV across groups is statistically significant, indicating that dementia does affect nWBV. An effect size of 0.087 indicates that this is a moderate effect. Visit also has a significant effect on nWBV, with a more substantial effect size of 0.401. In contrast the interaction between the two factors is not significant with a p-value of 0.219. This suggests that the effect of Visit on nWBV does not differ significantly across groups. Performing pairwise post-hoc tests reveal that there is a significant difference between the two visits, as well as between demented and nondemented patients. There are no statistically significant differences between the other pairs of groups. The interaction effects mirror this, with the only significant differences being between the demented and nondemented across the two visits.

Source	SS	DF1	DF2	MS	F	p	np2	eps
Group	0.034	2	141	0.017	6.712	0.002	0.087	-
Visit	0.007	1	141	0.007	94.251	<0.001	0.401	1.000
Interaction	<0.001	2	141	<0.001	1.534	0.219	0.021	-

Table 1: Summary of Mixed-Effects ANOVA for nWBV by Dementia Status and Visit

Repeating the process for MMSE (Table 2) we see that there is a statistically significant difference in MMSE by dementia status, with large effect size of 0.445. Visit also shows statistical significance in differences, although with a much lower effect size. The interaction effect has similar results, indicating that the way MMSE changes over time depends on status. Post-hoc tests once again indicate that visit is significant, highlighting time as an important factor in dementia assessment. There are statistically significant differences between converted and demented as well as demented and nondemented. Viewing interaction between group and visit, the same pairs showed statistical significance across both visits.

Source	SS	DF1	DF2	MS	F	p	np2	eps
Group	1328.421	2	140	664.211	56.212	<0.001	0.445	-
Visit	22.378	1	140	22.378	8.859	0.003	0.060	1.000
Interaction	17.000	2	140	8.500	3.365	0.037	0.046	-

Table 2: Summary of Mixed-Effects ANOVA for MMSE by Dementia Status and Visit

To validate our choice of methods we test assumption of sphericity and normality for our two ANOVAs. Both nWBV and MMSE data attained p-values approximately 1.000 using Mauchly's test of sphericity, satisfying the assumption of equal variances between visits. However, performing Shapiro-Wilk tests for normality of distributions by dementia status we see that while nWBV displays normality MMSE does not. We could consider replicating the study with non-parametric tests for more reliable results.

Group	p-Value	
	nWBV	MMSE
Nondemented	0.317	<0.001
Demented	0.540	<0.001
Converted	0.358	<0.001

Table 3: Results of Shapiro-Wilk Tests of Normality

Power Analysis: For a given power of 0.91, alpha of 0.05, and effect size of 0.7, 46 samples are needed in each group. Figure 5 visualizes the power curves, with larger effect sizes leading to much steeper growth in power with respect to sample size.

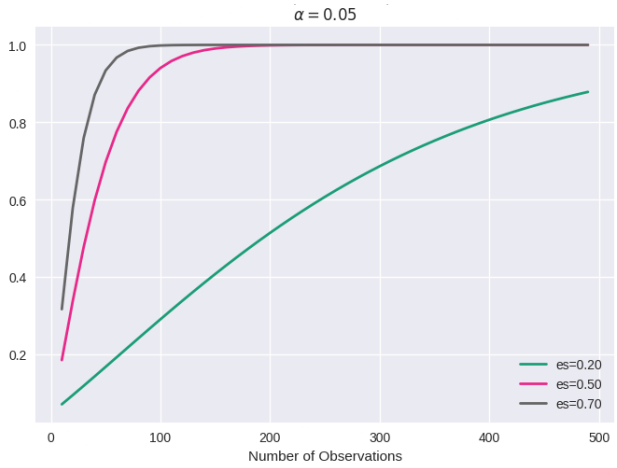

Figure 5: Power of Independent Samples T-Test

4. Conclusion

Research Question 1: How does dementia status affect changes in normalized whole brain volume (nWBV) over time?

While dementia status is associated with lower nWBV, the rate at which it changes does not vary by status. Differences across visits can mostly likely be attributed to an increase in age.

Research Question 2: Is the progression of cognitive decline, as measured by Mini-Mental State Examination (MMSE) scores, influenced by dementia status?

Dementia status seems to play a significant part in cognitive decline, as those diagnosed with dementia regressed while those unaffected remained consistent over a period of one year.

The results indicate that while dementia has both physical and cognitive impacts, its effect on mental capacity grows in severity over time. This highlights a need for additional resources to assess and address cognitive decline more consistently. Of note is that those that who were converted during the study had varying results, indicating that the impact of dementia is not so easily measured in the early stages.